

Warfare in Biodiversity Hotspots

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Abstract: *Conservation efforts are only as sustainable as the social and political context within which they take place. The weakening or collapse of sociopolitical frameworks during wartime can lead to habitat destruction and the erosion of conservation policies, but in some cases, may also confer ecological benefits through altered settlement patterns and reduced resource exploitation. Over 90% of the major armed conflicts between 1950 and 2000 occurred within countries containing biodiversity hotspots, and more than 80% took place directly within hotspot areas. Less than one-third of the 34 recognized hotspots escaped significant conflict during this period, and most suffered repeated episodes of violence. This pattern was remarkably consistent over these 5 decades. Evidence from the war-torn Eastern Afrotropical hotspot suggests that biodiversity conservation is improved when international nongovernmental organizations support local protected area staff and remain engaged throughout the conflict. With biodiversity hotspots concentrated in politically volatile regions, the conservation community must maintain continuous involvement during periods of war, and biodiversity conservation should be incorporated into military, reconstruction, and humanitarian programs in the world's conflict zones.*

Keywords: biodiversity conservation, biodiversity hotspots, conflict, protected areas, war, warfare ecology

Guerra en Sitios de Importancia para la Biodiversidad

Resumen: *Los esfuerzos de conservación son tan sustentables como el contexto social y político en que se llevan a cabo. El debilitamiento o colapso de los marcos sociopolíticos durante la guerra pueden llevar a la destrucción de hábitat y la erosión de las políticas de conservación, pero en algunos casos puede también conferir beneficios ecológicos debido a la alteración de los patrones de asentamiento y reducción en la explotación de recursos. Más de 90% de los conflictos armados entre 1950 y 2000 ocurrieron en países que contienen sitios de importancia para la biodiversidad, y más de 80% se llevaron a cabo directamente en áreas de importancia para la biodiversidad. Menos de un tercio de los 34 sitios de importancia para la biodiversidad reconocidos escaparon de conflictos significativos durante este período, y la mayoría sufrieron episodios de violencia repetidos. Este patrón fue sorprendentemente consistente en estas cinco décadas. La evidencia del sitio Afrotropical Oriental devastado por la guerra sugiere que la conservación de sitios de importancia para la*

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biodiversidad mejora cuando organizaciones no gubernamentales internacionales mantienen personal local en las áreas protegidas y permanecen involucradas durante el conflicto. Con la ubicación de los sitios de importancia para la biodiversidad en regiones volátiles políticamente, la comunidad de conservación debe mantener un involucramiento continuo durante los períodos de guerra, y la conservación de la biodiversidad debería incorporarse en programas militares, de reconstrucción y humanitarios en las zonas de conflicto.

Palabras Clave: áreas protegidas, conflicto, conservación de la biodiversidad, ecología bélica, guerra, sitios de importancia para la biodiversidad

Introduction

The long-term sustainability of conservation efforts depends on the social and political context within which they take place. During times of war and political unrest, environmental concerns recede in the face of violent conflict and socioeconomic disruption, contraction, or collapse. Historically, war has often led to abuses of wildlife and natural areas by soldiers and civilians alike (Nietschmann 1990a). Security concerns usually force the suspension of conservation activities (Hart et al. 1997; Shambaugh et al. 2001; Hart & Hart 2003), and international aid and attention concentrates on peacekeeping and humanitarian efforts. Protected areas may be left without paid staff, equipment, or infrastructure for the duration of the conflict (Hart et al. 1997; Zahler 2003). On the other hand, war can also relieve pressure on biodiversity through altered settlement patterns, the creation of *de facto* buffer zones, and reductions in resource-based economic activity (Nietschmann 1990b; McNeely 2003). The implications of war for biodiversity conservation are complex, multiscaled, and not limited to conflict zones or the time period of active hostilities. Indeed, Machlis and Hanson (2008) found that all stages of warfare (preparations, wars, and postwar activities) have far-reaching environmental impacts.

The concept of biodiversity hotspots, pioneered by ecologist Norman Myers as a template for setting global conservation priorities (Myers 1988; Myers et al. 2000), has resulted in the allocation of considerable conservation resources to these biologically important regions (Brooks et al. 2006). Defined by their exceptional species endemism and extensive loss of habitat, the 34 identified hotspots harbor the entire ranges of at least 42% of terrestrial vertebrate species and at least 50% of known plant species within extant habitat that covers only 2.3% of the earth's land surface (Mittermeier et al. 2004). Hotspots are particularly sensitive to human disturbance and much of their remaining high-quality habitat persists only within protected areas (Mittermeier et al. 2004). Many hotspots also lie in centers of political volatility (Mittermeier et al. 2004), making the impacts of warfare a critical aspect of their long-term conservation.

We analyzed the overlap between biodiversity hotspots and the areas of violent conflict from 1950

to 2000 and reviewed the major biodiversity conservation issues associated with warfare. Evidence from the volatile Eastern Afromontane hotspot illustrates the tenuous nature of biodiversity conservation in times of war and offers important lessons for scientists, the conservation community, and policy makers.

Biodiversity Hotspots in Volatile Regions

With their high biological richness and limited extent, biodiversity hotspots may be particularly sensitive to the impacts of conflict. To qualify as a hotspot, a region must support 1500 endemic vascular plant species (0.5% of the estimated 300,000 world total), and it must have lost 70% or more of its original vegetative cover (Mittermeier et al. 1999; Myers et al. 2000). Vertebrate endemism is not a hotspot criterion, but in many areas, it approaches the high rates observed in the flora. Remarkably, some three-quarters of the world's most threatened mammals, birds, and amphibians occur only in the hotspots (Mittermeier et al. 2004). Targeting these diverse regions first provides a greater return on the investment of limited conservation dollars and gives hope that a significant portion of global biodiversity can be preserved in the face of development, population growth, climate change, and other pressures. Several nongovernmental organizations (NGOs) and funding agencies prioritize investments in hotspots, such as the Critical Ecosystem Partnership Fund, a joint mechanism sponsored by Conservation International, l'Agence Française de Développement, the Global Environment Facility, the Government of Japan, the World Bank, and the MacArthur Foundation. The total investment in hotspot-related projects exceeded \$750 million in 2003 (Myers & Mittermeier 2003) and continues to increase.

To assess the spatial overlap between hotspots and warfare, we compared the geographic range of hotspots with the locations of wars between 1950 and 2000 (Fig. 1). We defined *war* as any armed conflict with over 1000 total casualties. We used 3 independent assessments of the 20th-century wars in the analysis (Arnold 1991; Sarkees 2000; Gleditsch et al. 2002), and the combined data set included all armed conflicts with >1000 casualties

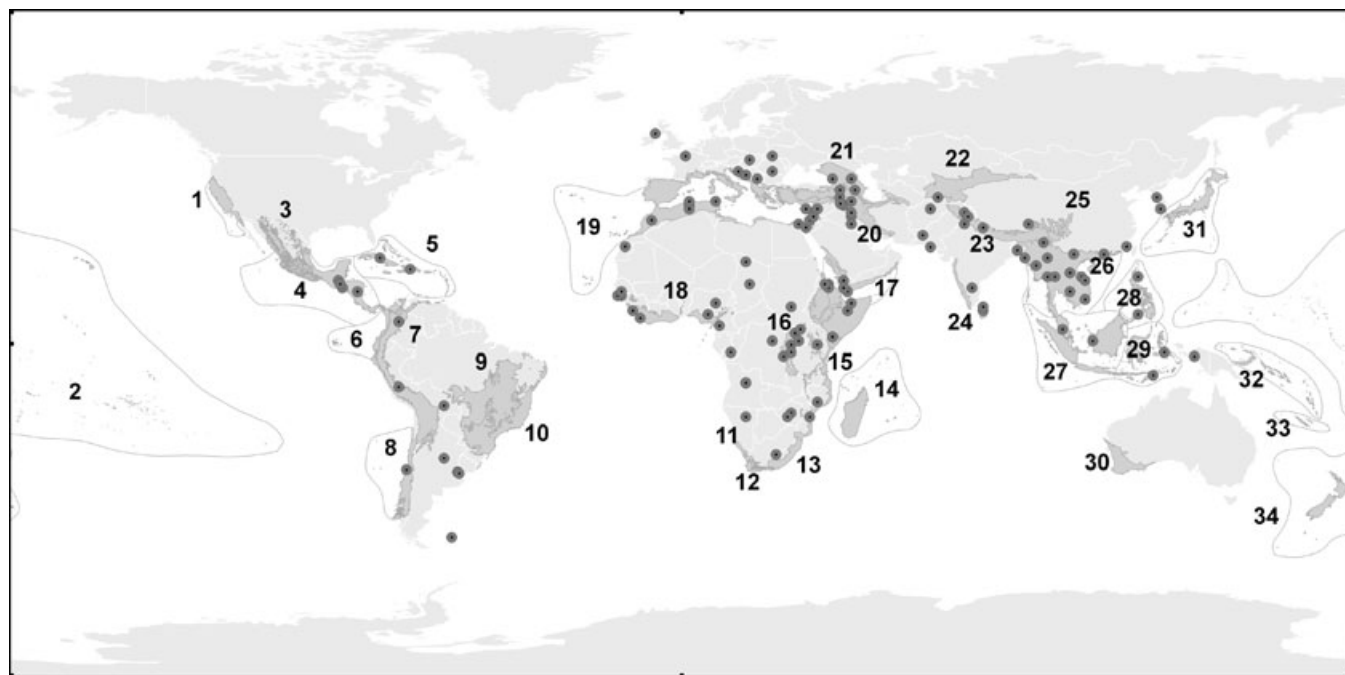


Figure 1. The world's 34 biodiversity hotspots (numbers) (Mittermeier et al. 2004) and the location of all armed conflicts with over 1000 casualties between 1950 and 2000 (points) (conflict data from Arnold 1991; Sarkees 2000; Gleditsch et al. 2002). Biodiversity hotspots: 1, California Floristic Province; 2, Polynesia, Micronesia; 3, Madrean Pine-Oak Woodlands; 4, Mesoamerica; 5, Caribbean Islands; 6, Tumbes - Chocó - Magdalena; 7, Tropical Andes; 8, Chilean Winter Rainfall and Valdivian Forests; 9, Cerrado; 10, Atlantic Forest; 11, Succulent Karoo; 12, Cape Floristic Region; 13, Maputaland - Pondoland - Albany; 14, Madagascar and the Indian Ocean Islands; 15, Coastal Forests of Eastern Africa; 16, Eastern Afromontane; 17, Horn of Africa; 18, Guinean Forests of West Africa; 19, Mediterranean Basin; 20, Irano-Anatolian; 21, Caucasus; 22, Mountains of Central Asia; 23, Himalayas; 24, Western Ghats and Sri Lanka; 25, Mountains of Southwest China; 26, Indo-Burma; 27, Sundaland; 28, Philippines; 29, Wallacea; 30, Southwest Australia; 31, Japan; 32, East Melanesian Islands; 33, New Caledonia; 34, New Zealand.

listed in any of the 3 studies. No further distinction was made regarding the scale or intensity of the conflicts, and conflicts of smaller magnitude (<1000 casualties) were not considered. Where the 3 assessments did not agree on the subdivisions or length of a long-term war, a more inclusive time frame was used. The resulting compilation totaled 146 international, colonial, and intranational conflicts for the study period.

Biodiversity hotspots range in size from the small New Caledonia island group to the broad reach of the Mediterranean Basin. Their original extent encompassed 16% of the planet's land area, but the remaining habitat within them covers only 2.3% (Mittermeier et al. 2004). We compared lists of nations represented in each hotspot with the locations of the 146 analyzed wars (Table 1). We determined whether a war occurred within a country's hotspot region with the greatest specificity possible. For example, the Uganda-Tanzania war of 1978-1979 involved 2 nations with biodiversity hotspots (the Eastern Afromontane hotspot in both countries and the coastal forests of Eastern Africa hotspot in Tanzania), but the war played out in the interior lowlands, far from the hotspot

areas. Similarly, none of the urban-centered 1955 military revolts in Argentina occurred within the small fractions of that country located in hotspots.

On the basis of these criteria, 118 of 146 conflicts (81%) took place wholly or partially within biodiversity hotspots. When we used the historical percentage of land covered by hotspots to generate an expected value, this proportion was highly significant (one-tailed; $\chi^2 = 456$, $p < 0.01$, $df = 1$). Only 11 of the 34 hotspots escaped the 1950-2000 period without hosting a significant armed conflict, and most regions suffered repeated episodes of violence. Because the indirect effects of warfare can also significantly affect a nation's biodiversity (see below), we identified an additional 14 conflicts that occurred within hotspot countries but outside their specific hotspot regions (Table 1). Including these conflicts, 132 of the wars (90%) took place in countries containing hotspots, again significantly greater than expected (one-tailed; $\chi^2 = 601$, $p < 0.01$, $df = 1$), and only 10 hotspots were wholly within countries that did not host a significant conflict.

To examine whether these results were consistent over time, we assigned hotspot conflicts to their

Table 1. Biodiversity hotspots, the countries in which they are found, and the armed conflicts with over 1000 casualties that took place within them between 1950 and 2000 (conflict data from Arnold 1991; Sarkees 2000; Gleditsch et al. 2002).

<i>Biodiversity hotspot</i>	<i>Nations represented in hotspot</i>	<i>Armed conflicts (dates)^{a,c}</i>
Atlantic Forest	Argentina, Brazil, Paraguay, Uruguay	Argentina–Military Revolution (1955), ^b Argentina–Montoneros Conflict (1973–1977), ^b Argentina–Dirty War Conflict (1976–1980) ^b none
California Floristic Province	Mexico, the United States	none
Cape Floristic Region	South Africa	South Africa–ANC–PAC Conflicts (1981–1993)
Caribbean Islands	Anguilla (U.K.), Antigua and Barbuda, Aruba (the Netherlands), the Bahamas, Barbados, British Virgin Islands, the Cayman Islands (U.K.), Cuba, Dominica, the Dominican Republic, Grenada, Guadeloupe (France), Haiti, Jamaica, Martinique (France), Montserrat (U.K.), the Netherlands Antilles (the Netherlands), Puerto Rico (U.S.A.), St. Barthélemy (France), St. Kitts and Nevis, St. Lucia, St. Martin (France), St. Vincent and the Grenadines, Turks and Caicos (U.K.), U.S. Virgin Islands	Cuba–Castro Revolution (1958–1959), Dominican Republic Conflict (1965)
Caucasus	Armenia, Azerbaijan, Georgia, Iran, Russia, Turkey	USSR–Ukraine–UPA Conflict (1945–1950), ^b Russo–Hungarian War (1956), ^b Turkey–Extremist Conflicts (1977–1980), Iranian Revolution (1978–1979), Iran–Mujahedin Conflict (1981–1982), Georgia–Gamsakurdia Conflict (1991–1994), Azerbaijan–Karabakh Conflict (1991–1994), Russia–Chechnya Conflict (1992–present)
Cerrado	Bolivia, Brazil, Paraguay	none
Chilean Winter Rainfall–Valdivian Forests	Argentina, Chile	Chile–Pinochet Revolution (1973)
Coastal Forests of Eastern Africa	Kenya, Mozambique, Somalia, Tanzania	Mozambique Independence (1964–1977), Mozambique–RENAMO Conflict (1979–1992)
East Melanesian Islands	Papua New Guinea, the Solomon Islands, Vanuatu	none
Eastern Afrotropical	Burundi, the Democratic Republic of Congo (DR Congo), Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Saudi Arabia, Somalia, Sudan, Tanzania, Uganda, Yemen, Zambia, Zimbabwe	Yemen Conflicts (1962–1969; 1986; 1994), British–Mau–Mau Conflict (1952–1956), DR Congo Conflicts (1960–1965; 1993; 1996–1997; 1998–present), Rwanda–Tutsi–Hutu Conflicts (1962–1963; 1990–1993; 1994) Sudan Conflict (1963–1972), Mozambique Independence (1964–1977), Uganda–Baganda Conflict (1966), ^b Burundi–Tutsi–Hutu Conflicts (1972; 1988; 1991; 1993–present), Zimbabwe Independence (1972–1979), Uganda–Tanzanian War (1978–1979), ^b Ethiopia–Tigray Conflict (1978–1991), Uganda–NRA Revolution (1980–1985), Sudan–SPLA Conflict (1983–2005), Zimbabwe–ZAPU Conflict (1982–1985), ^b Uganda–LRA Conflict (1996–present), ^b Ethiopia–Eritrea War (1998–2000)
Guinean Forests of West Africa	Benin, Cameroon, Côte d'Ivoire, Equatorial Guinea, Ghana, Guinea, Liberia, Nigeria, Sierra Leone, São Tomé and Príncipe, Togo	Cameroon Independence (1955–1960), Guinean Independence (1962–1974), Nigeria–Biafran Conflict (1967–1970), Nigeria–Muslim Conflicts (1980–1981; 1984), ^b Liberia Conflicts and Revolutions (1989–1990; 1992–1995; 1996), Sierra Leone–RUF Conflict (1991–1996)
Himalayas	Bhutan, India, Myanmar, Nepal, Pakistan, Tibet (China)	India–CPI Conflict (1948–1951), ^b India–Pakistan Kashmir Wars (1964–1965; 1971; 1999), Sino–Tibetan War (1950–1951), China–Tibetan Conflict (1956–1959), Sino–Indian War (1962), China–Red Guard Conflict (1967–1968), Pakistan–Baluchi Conflict (1973–1977), ^b India–Kashmiri Conflict (1985–present), Pakistan–Mohajir Conflict (1994–1995) ^b

continued

Table 1. (continued)

<i>Biodiversity hotspot</i>	<i>Nations represented in hotspot</i>	<i>Armed conflicts (dates)^a</i>
Horn of Africa	Djibouti, Eritrea, Ethiopia, Kenya, Oman, Saudi Arabia, Somalia, Sudan, Yemen	Yemen Conflicts (1962–1969; 1986; 1994), Kenya–Somalia–Shifa War (1963–1967), Ethiopia–Eritrean Conflict (1974–1991), Ethiopia–Somalia Conflict (1976–1977), Ethiopia–Somalia War (1977), Somalia–Clan Conflicts (1982–present), Ethiopia–Eritrea War (1998–2000)
Indo-Burma	The Andaman Islands (India), Bangladesh, Cambodia, China, Laos, Malaysia, Myanmar, Vietnam	French Indo-China Independence (1945–1954), India–CPI Conflict (1948–1951), ^b Burma Ethnic Conflicts (1950–1951; 1968–1980; 1964–present) Burma–BCP–Kachin Conflicts (1948–1988; 1983–1995), Vietnam Conflict (1960–1965), Vietnam War (1965–1975), Laos–Pathet Lao Revolution (1960–1973), China–Red Guard Conflict (1967–1968), Thailand–CPT Conflict (1970–1973), Cambodia–Khmer Rouge Revolution (1970–1975), Pakistan–Bengali Conflict (1971), Bangladesh War (1971), Vietnam–Cambodia War (1975–1979), Cambodia–Khmer Rouge Conflicts (1978–1991; 1993–1997), Sino-Vietnamese Wars (1979; 1987)
Irano-Anatolian	Armenia, Azerbaijan, Georgia, Iraq, Iran, Turkey, Turkmenistan	Iraq–Shammar/Military Conflict (1958–1959), ^b Iraq–Kurd Conflicts (1961–1963; 1974–1975; 1985–1993; 1996), Turkey–Extremist Conflicts (1977–1980), Iranian Revolution (1978–1979), Iran–Iraq War (1980–1988), First Gulf War (1990–1991), ^b Turkey–Kurd Conflict (1991–present)
Japan	Japan	none
Madagascar and the Indian Ocean Islands	Comoros, Illes Esparses (France), Madagascar, Mayotte (France), Mauritius (including Rodrigues), Réunion (France), the Seychelles (including Aldabra)	none
Madrean Pine-Oak Woodlands	Mexico, the United States	none
Maputaland – Pondoland – Albany	Mozambique, South Africa, Swaziland	Mozambique Independence (1964–1977), Mozambique–RENAMO Conflict (1979–1992), South Africa–ANC–PAC Conflicts (1981–1993)
Mediterranean Basin	Albania, Algeria, Azores, Bosnia and Herzegovina, Bulgaria, the Canary Islands, Cape Verde Islands, Croatia, Cyprus, Egypt, France, Gibraltar (U.K.), Greece, Israel, Italy, Jordan, Lebanon, Libya, Macedonia, Madeira Islands, Malta, Monaco, Montenegro, Morocco, Portugal, Selvages, Slovenia, Spain, Syria, Tunisia, Turkey	Franco-Tunisian Conflict (1952–1954), Moroccan Independence (1953–1956), Algerian Independence (1954–1962), Israel–Palestinian Conflict (1955–present), Suez–Sinai War (1956), Lebanon Conflict (1958), Franco–OAS Conflict (1961–1962), Algerian Conflicts (1962–1963; 1992–present), Six-day War (1967), Israel–Egypt War (1969–1970), Jordan–Palestinian Conflict (1970), Yom Kippur War (1973), Turko-Cypriot War (1974), Lebanon Conflict (1975–1990), Turkey–Extremist Conflicts (1977–1980), Lebanon War (1982), Yugoslavia–Serbia–Croatia Conflict (1991–1992), Bosnia and Herzegovina–Serb Conflict (1992–1995)
Mesoamerica	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Panama	Guatemalan Revolution (1954), Guatemalan Conflicts (1966–1995), Football War (1969), Nicaragua Revolution (1978–1979), El Salvador Conflict (1979–1992), Nicaragua–Contra Conflict (1982–1990)
Mountains of Central Asia	Afghanistan, China, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan	China–Red Guard Conflict (1967–1968), Afghanistan–USSR–Mujahadin–Taliban Conflicts (1978–present), Tajikistan–PDA Conflict (1992–1997)
Mountains of Southwest China	China, Myanmar	China–Communist Revolution (1946–1950), China–Red Guard Conflict (1967–1968)
New Caledonia	New Caledonia (France)	none
New Zealand	New Zealand, Lord Howe and Norfolk Islands (Australia)	none
Philippines	The Philippines	Philippines–Huks Conflict (1946–1954), Philippines–Moros Conflict (1972–present), Philippines–NPA Conflict (1972–present)

continued

Table 1. (continued)

<i>Biodiversity hotspot</i>	<i>Nations represented in hotspot</i>	<i>Armed conflicts (dates)^a</i>
Polynesia - Micronesia	American Samoa (U.S.A.), the Cook Islands (New Zealand), Easter Island (Chile), Federated States of Micronesia, Fiji, French Polynesia (France), Guam (U.S.A.), Hawaii (U.S.A.), Kiribati, Marshall Islands, Nauru, Niue (New Zealand), Northern Mariana Islands (U.S.A.), Palau, Pitcairn Islands (U.K.), Samoa, the Solomon Islands, Tokelau (New Zealand), Tonga, Tuvalu, Vanuatu, Wake Island (U.S.A.)	none
Southwest Australia Succulent Karoo	Australia Namibia, South Africa	none Namibian Independence (1975–1988), South Africa–ANC–PAC Conflicts (1981–1993)
Sundaland	Brunei Darussalam, Indonesia, Malaysia, Nicobar Islands (India), Singapore, Thailand	British Malaya–CPM Conflict (1948–1957), Indonesia–Darul Islam Conflict (1953), Indonesia–Leftist Conflict (1956–1960)
Tropical Andes	Argentina, Bolivia, Chile, Colombia, Ecuador, Peru, Venezuela	Colombia–Violencia Conflict (1949–1962), Bolivian Revolution (1952), Argentina–Montoneros Conflict (1973–1977), Argentina–Dirty War Conflict (1976–1980), ^b Peru–Shining Path/MRTA Conflict (1982–1995), Colombia–FARC–ELN Conflicts (1984–present)
Tumbes - Chocó - Magdalena Wallacea	Colombia, Ecuador, Panama, Peru Timor-Leste, Indonesia	Colombia–Violencia Conflict (1949–1962), Colombia–FARC–ELN Conflicts (1984–present) Indonesia–Moluccan Conflict (1950) Indonesia–Leftist Conflict (1956–1960), East Timor Independence (1975–1989; 1992; 1997–1998)
Western Ghats and Sri Lanka	India, Sri Lanka	India–CPI Conflict (1948–1951), ^b Sri Lanka–JVP Conflict (1971; 1987–1989), Sri Lanka–Tamil Conflict (1983–present) ^c

^a Conflicts are listed under the most relevant hotspot, but may appear more than once if they affected multiple areas; war, international conflicts; independence, conflicts resulting in freedom from colonial rule; revolution, internal conflicts resulting in regime change; conflict, all other internal armed struggle. Dates separated by semicolon indicate distinct conflict periods.

^b Conflict took place within a country containing biodiversity hotspots, although not directly within the hotspot areas.

^c JVP, Janatha Vimuktibi Peramuna (People's Liberation Front); CPI, Communist Party of India; FARC, Fuerzas Armadas Revolucionarias de Colombia (Revolutionary Armed Forces of Columbia); ELN, Ejército de Liberación Nacional (National Liberation Army); MRTA, Movimiento Revolucionario Túpac Amaru (Túpac Amaru Revolutionary Movement); CPM, Communist Party of Malaya; ANC, African National Congress; PAC, Pan Africanist Congress; NPA, New People's Army; PDA, Popular Democratic Army; RENAMO, Resistência Nacional Moçambicana (Mozambican National Resistance); CPT, Communist Party of Thailand; RUF, Revolutionary United Front; LRA, Lord's Resistance Army; ZAPU, Zimbabwe African People's Union; SPLA, Sudan People's Liberation Army; NRA, National Resistance Army; UPA, Ukrayins'ka Povstans'ka Armia (Ukrainian Insurgent Army)

corresponding decade between 1950 and 2000. Conflicts that spanned multiple decades were allocated in equal portion among the decades in question (e.g., allocating the Peruvian Shining Path Conflict [1982–1995] as half in the 1980s and half in the 1990s). There were 20 conflicts in hotspots in the 1950s, 18 in the 1960s, 25 in the 1970s, 14 in the 1980s, and 20 in the 1990s. This distribution of conflicts over decades was not significantly different from the value expected, given the average number of conflicts per decade for the period 1950–2000 ($\chi^2 = 4.41$, $p = 0.05$, $df = 4$). The results for conflicts in countries containing hotspots were qualitatively similar. This pattern of violence appears to be continuing into the 21st century. Nineteen active conflicts of similar magnitude (> 1000 casualties) occurred during 2004, with 14 of them (74%) directly in hotspots (Harbom & Wallenstein

2005). Again, this was highly significant ($\chi^2 = 47$, $p \ll 0.01$, $df = 1$).

Our analysis revealed a startling pattern. Armed conflicts were highly prevalent and consistent in the world's most biologically important regions, underscoring the urgency of understanding the effects of warfare in the context of biodiversity conservation.

Warfare and Biodiversity Conservation

The broad environmental impacts of warfare are summarized in several reviews (Gleditsch 1998; Jarrett 2003; Machlis & Hanson 2008) and an edited volume (Austin & Bruch 2000). Other studies have focused on more specific topics, including the effects of conflict on

tropical forests (McNeely 2003; Price 2003; De Jong et al. 2007), wildlife (Dudley et al. 2002), and natural resources of a particular conflict area (e.g., Sierra Leone; Richards 1996). We examined the major implications of warfare for biodiversity conservation, emphasizing the consequences and opportunities most relevant to hotspot regions.

Consequences

The impacts of war on natural landscapes date to the earliest military histories and have increased over time with the scale and technologies of warfare. In the modern era, chemical, biological, and nuclear weapons have expanded the potential for catastrophic, landscape-level change and long-term contamination (Glasstone & Dolan 1977; Dudley & Woodford 2002). During the Vietnam War, aerial application of Agent Orange and other herbicides defoliated 14% of that country's forest cover and over 50% of its coastal mangroves (SIPRI 1976; Hastings 2000). Intended to deprive the enemy of shelter and sustenance, such tactical assaults on the biological fabric of a country have become known as "ecocide" (Weisberg 1970).

Modern wars, particularly intranational conflicts, often play out in remote areas, where armed factions seek the cover afforded by deep forests, mountains, and other rugged landscapes (Nietschmann 1990a; McNeely 2003). Protected-area boundaries lose effectiveness in this context, usually resulting in the evacuation of field staff and suspension of conservation activities (Hart et al. 1997). Local proliferation of small arms leads to increased hunting for bushmeat, wildlife products, and sport, often by the soldiers themselves. Examples include the decimation of Uganda's elephant (*Loxodonta africana*) and hippopotamus (*Hippopotamus amphibius*) populations during the 1970s (Eltringham & Malpas 1980) and the more recent war-related poaching in neighboring Democratic Republic of (DR) Congo, where hippopotamus herds in Virunga National Park have been reduced by more than 95% (Muir 2006).

The indirect effects of conflict often have more far-reaching impacts than the direct destruction on battlegrounds. Military expenditures can come at the expense of other government programs, including natural resource management. With ongoing wars in Afghanistan and Iraq, recent U.S. budget proposals have included increased defense spending alongside an 8% reduction for the budget of the U.S. Forest Service (Daly 2008) and up to an 11% reduction in cuts for the U.S. National Park Service (over 3 years) (Stearns 2006). For insurgents and rebel groups, the natural resources within their territories often provide their main source of revenue (Dudley et al. 2002). Examples include the so-called conflict diamonds sold to fund civil wars in Angola, Liberia, DR Congo, and Sierra Leone (Global Witness 2000), exten-

sive timber harvests in Sierra Leone, Cambodia, and DR Congo (Richards 1996; Le Billon 2000; Laurance 2001), and the production of illicit drugs in Afghanistan, Southeast Asia, and Latin America (Cornell 2005). These activities often continue after the conflict as natural resources are liquidated to repay war debts, fund reconstruction, and bolster the power base of postwar governments (e.g., Le Billon 2000).

The humanitarian crises accompanying wars can also have devastating impacts on wildlife and natural resources. Refugees and displaced persons are in no position to consider environmental impacts when choosing where to hunt, gather firewood, or build encampments. During the civil war in Rwanda in the mid-1990s, over 2 million refugees flooded camps in neighboring countries, and the demand for fuelwood led to the deforestation of more than 300 km² of land in Virunga National Park (McNeely 2003). Delays in repatriation and the persistence of unexploded ordnance can last for years or decades, perpetuating the environmental impacts of the conflict.

Opportunities

Although biodiversity conservation typically suffers during wartime, the altered human activity in conflict areas sometimes creates tangible conservation opportunities. For example, buffer zones between opposing forces can become reservoirs for biodiversity. This pattern has been observed among tribal territories in New Guinea and the Amazon (McNeely 2003) and in the remarkable wildlife concentrations encountered by the Lewis and Clark Expedition in war zones between Native American nations (Martin & Szuter 1998). The demilitarized zone (DMZ) separating North and South Korea provides the most striking modern example of this concept. Uninhabited for decades, it has created a 4-km-wide de facto nature reserve that spans the Korean Peninsula and harbors numerous threatened species (Kim 1997). Transboundary peace parks have been established or proposed to conserve biodiversity and aid conflict resolution in several disputed areas, including Kashmir (India/Pakistan) and the Mesopotamian marshes (Iran/Iraq) (Ali 2007). Furthermore, military bases and training reserves often set aside large off-limit areas that remain natural as surrounding land develops. In the military repositioning following the end of the Cold War, decommissioned bases in the United States and the former Soviet Union became highly sought after by conservation groups and development interests (e.g., Hamilton 1995; Webster 2002).

Although war zones may provide direct benefits to battlefield scavengers (Nietschmann 1990a) or other opportunistic species, most war-related conservation opportunities lie in the altered human activity patterns in conflict areas. Reduced economic activity can make wartime a recovery period for certain exploited resources, and the risk and uncertainty of living in unstable regions can

forestall human expansion. Stocks of European plaice (*Pleuronectes platessa*) in the North Sea rebounded dramatically after reductions in commercial fishing during both World War I and World War II (Smith 1994). In Myanmar insurgent activity helped keep the Hukawng Valley isolated for over 30 years, and it now forms the nexus for the country's largest nature reserve (Rabinowitz 2005). Nietschmann (1990b) describes the widespread recovery of wildlife and forest resources during Nicaragua's Sandinista and Contra conflicts in the 1970s and 1980s. In neighboring Costa Rica the recently created Maquenque National Wildlife Refuge encompasses 60,000 ha of a forested border region that once served as a dangerous staging area for Contra rebels and has remained sparsely settled ever since.

Buffer zones, resource recovery, and delayed development are highly case-specific and limited to certain regions and conditions. They present a postwar opportunity that requires continuous involvement and proactive planning, such as the efforts already underway for conservation in Korea's DMZ (Kim 1997).

Case Study: Lessons from the Eastern Afromontane Hotspot

Close examination of one hotspot offers an illustrative case study for the impacts of warfare on biodiversity conservation. The Eastern Afromontane hotspot includes high-elevation habitats stretching intermittently from Zimbabwe north to the Arabian Peninsula (Mittermeier et al. 2004). Although politically volatile throughout, this hotspot has been most notoriously unstable in the Albertine Rift area. Since 1990 civil war and genocide in Rwanda, followed by war and unrest in neighboring DR Congo, have left millions of people dead or displaced and have had significant impacts on the region's biodiversity (Biswas & Tortajada-Quiroz 1996; Kanyamibwa 1998; Kalpers 2001). The conflict and sociopolitical breakdown continue in large areas of eastern DR Congo, although postwar recovery has brought a measure of stability to Rwanda.

Conservationists and field scientists have described the challenges of preserving biodiversity in this chaotic landscape (Hart et al. 1997; Kalpers 2001; Plumptre et al. 2001; Hart & Hart 2003). These authors agree on 2 primary themes: the importance of maintaining continuous support for protected areas throughout the conflict period and the importance of training and supporting dedicated staff from local communities. In Rwanda and DR Congo, national-level conservation funding evaporated as government control weakened and the major international development programs withdrew their support (Kalpers 2001; Plumptre et al. 2001; Hart & Hart 2003). International conservation NGOs (e.g., The International Gorilla Conservation Program, The Dian Fossey Gorilla

Fund International, and Wildlife Conservation Society), however, had better flexibility to maintain contact with individual protected areas. Although national and expatriate senior staff were targets for persecution and were forced to evacuate, junior wardens and rangers in several areas undertook dramatic efforts to continue patrols and monitor activities (Hart et al. 1997). Salaries and other support provided by NGOs (e.g., safe houses and funds for rebuilding homes) during the conflict played a vital role in maintaining morale and continuity of operations (cited in Plumptre et al. 2001).

In Rwanda 4 protected areas occur within the Eastern Afromontane hotspot. International NGOs continued support for local staff of Volcanoes National Park and Nyungwe Forest Reserve throughout the civil war, genocide, and volatile postwar period. Despite the unrest, Volcanoes National Park maintained intact boundaries and stable ungulate populations over the course of the conflict (Plumptre et al. 2001), and its population of critically endangered mountain gorillas (*Gorilla beringei beringei*) actually increased during this period (Weber 2004). The involvement of NGOs after the war helped the park restart tourism and research and averted proposed road-building and cattle-ranching projects (Plumptre et al. 2001). Although poaching intensified in Nyungwe Forest, local rangers continued patrolling the core of the reserve (Hart et al. 1997; Plumptre et al. 2001), and international NGOs helped it gain full national park status during the postwar reorganization. In contrast the smaller and less-known Gishwati and Makura forest reserves received little or no international NGO attention during the 1990s. A reconnaissance survey in 2000 found that Gishwati had been almost completely deforested. Makura was reduced to less than half its historical extent, and its populations of endemic birds are no longer thought to be viable (Plumptre et al. 2001).

The continuing strife in DR Congo has prevented thorough biological surveys, but initial reports from Kahuzi-Biega National Park suggest a similar pattern. A small population of the rare Grauer's gorilla (*Gorilla beringei graueri*) persists in the highland sector, where the staff has received NGO support and remained active (Hart & Liengola 2005). Outside this narrow zone, however, rebel-controlled mining operations, logging, settlements, encroachment, and widespread poaching have progressed unopposed for years, devastating the park's natural resources. Hunters report steep declines in the availability of large game, including elephants and gorillas, and conservationists believe these species are at risk of extirpation (Redmond 2001).

Conclusions

Like most other societal challenges, conserving natural resources during wartime is complex and case-specific.

Biodiversity can suffer from the general breakdown in law and structure, but in some cases, this very chaos brings opportunities for conservation. Maintaining ecological integrity in these situations requires functioning political, economic, and social systems or, when they are absent, continued international engagement and quick action in the aftermath. Conservation scientists and NGOs need the flexibility and resources to remain engaged throughout conflict periods and should be poised to assist countries during postwar recovery.

The alarming geographic overlap between biodiversity hotspots and armed conflicts underscores the urgency of this issue. Possible drivers of the war-hotspots trend include the tactical advantages afforded to rebel groups by remote and inaccessible landscapes (Nietschmann 1990a; McNeely 2003), the relationships between population growth and environmental scarcity (Homer-Dixon 1999), and local historical, cultural, and political issues (Peluso & Watts 2001). The degradation of biodiversity hotspots may also create positive feedbacks with warfare by reducing ecosystem health and therefore contributing to future resource conflicts (Homer-Dixon 1999; Klare 2001). High biodiversity areas often overlap with areas of high human population density (Balmford et al. 2001) and high cultural diversity (Nietschmann 1992; Maffi 2005), and resource-rich protected areas may themselves become objects of contention (Brandon et al. 1998). A detailed investigation of the causes of war in biodiversity hotspots is beyond the scope and purpose of this essay, but it remains a high priority for future research.

Our findings have 2 clear and important policy implications. First, conservation organizations, rather than working only in stable countries, must develop programs in war-torn regions if they are to be effective in conserving global biodiversity. Second, whether to ameliorate root causes or to mitigate effects, biodiversity conservation should be integrated into military, reconstruction, and humanitarian programs in the world's conflict zones. Potential planning strategies include the development of contingencies to support national institutions and local protected area staff throughout conflicts; collaboration with military professionals to reduce the effects of warfare; natural resource management training for soldiers, humanitarian workers, and peacekeeping forces; promotion of conservation and sustainable use of natural resources in postwar recovery policies, including creation of peace parks along disputed borders; and strengthened enforcement of international conventions governing war-related environmental damage. Although we focused on biodiversity hotspots, these policy implications may also be relevant to high-biodiversity wilderness areas, endemic bird areas, or other global conservation priorities (Brooks et al. 2006).

We have discussed the conservation opportunities associated with warfare, but of course, this does not mean warfare is good. Rather, we raise these issues to advocate

quick readiness when appropriate situations arise, particularly the conservation of buffer zones, peace parks, and former military lands. In addition, we encourage support for local conservationists and protected area staff during conflict periods, but we in no way suggest intentionally putting people in harm's way. Local staff often remain in conflict areas precisely because those areas are their homes, making continued support both an ethical imperative and a good conservation strategy.

Biodiversity has experienced setbacks and occasional gains from wartime conditions and will continue to be affected by the complex geopolitical landscape of the 21st century. The ability of the conservation community to meet these challenges will help determine what measure of biodiversity this generation leaves for the next.

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